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TRANSACTIONS

OF THE

ROYAL IRISH ACADEMY.

I. *Upon a new Method of investigating the Specific Heats of the Gases.*

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Read 16th March, 1837.

THERE is scarcely a problem within the range of experimental physics, which, in modern times, has attracted so much attention as that which has for its object the determination of the specific heats of what are sometimes, though improperly, called the permanently elastic fluids. It is a problem, also, encompassed by so many difficulties, that the best results hitherto obtained are usually considered but as approximations; and the simple law to which the more recent results would appear to point, that under equal volumes all gases have the same specific heat, is, it is scarcely necessary to remark, far from being universally admitted. The methods of investigation heretofore pursued have been of a direct nature, or have consisted in the estimation of the respective amounts of caloric evolved by equal weights, or equal volumes of the different gases in cooling through the same range of temperature—the results in the latter case being divided by the specific gravities, in order to pass to the relative capacities of equal masses. But a given weight of air, in cooling through any number of degrees, will evolve different quantities of caloric, according to the circumstances under which its refrigeration is effected. If it be permitted to shrink as it cools, so that its elasticity may continue constant, it will obviously extricate more heat than if its primitive volume be maintained by being enclosed in, for example, some unyielding envelope; inasmuch as experiment proves that after a gas has cooled down in the latter predicament, a considerable rise of temperature takes place, when upon admitting the atmosphere it is subjected to its original pressure. The specific heat of a gas, therefore, it should be borne in mind, admits of a double interpretation, or is different according as the gas is considered to be of a constant volume or of a constant elasticity.

Now, of the many philosophers who have applied themselves to researches in reference to the specific heats of the æriform fluids, some (as Crawford, Clement, and Desormes, Marcet and De la Rive,) have experimented upon the gases maintained at a constant volume; while others, (as Lavoisier, Laplace, Gay Lussac, Leslie, De la Roche, and Berard, and finally Haycraft,) upon the same at a constant elasticity; so that for this reason, even if there were no other, their experimental results, and the numerical conclusions thence deduced, do not all admit of immediate comparison.

But though we collate those results alone which are deduced by the same method, a great discordancy will be found to exist between them. The method of Cawford, Clement, and Desormes, and of Marcet and De la Rive, were in principle the same, as all operated on the gases preserved of a constant volume; and, nevertheless, the conclusions at which they have arrived are widely different. Nor is there a closer agreement between the numbers arrived at by those who have essayed the solution of the problem, by determining the quantities of caloric, evolved by the different gases in cooling, under a constant pressure, through the same range of temperature. Some, as Leslie and Haycraft, have arrived at the law, since so ably advocated by Marcet and De la Rive, that all gases have, under equal volumes, the same capacity for caloric, or what amounts to the same thing, that the specific heats of equal weights are reciprocally proportional to their specific gravities; while others, as Lavoisier and Laplace, Gay Lussac, and, in particular, De la Roche and Berard, have obtained results quite irreconcilable with so simple a view of the subject.

The most interesting, if not the most recent inquiries in reference to the specific heats of the gases, have been conducted by M. Dulong of Paris. In his memoir upon the subject, published in the Annales De Chimie, (tom. xli. p. 113,) this distinguished philosopher commences with a critique upon the processes of Haycraft, and of Marcet and De la Rive, having for its object to show that the law of "equal specific heats under equal volumes,"* at which they had arrived, however strongly recommended by its simplicity, cannot be considered as unequivocally established by their experiments. It is difficult, indeed, to urge any valid objection against the method of Haycraft. In principle it was the same with that previously practised by De la Roche and Berard, and he, in addition, took the very proper precaution of operating upon gases deprived of all hygrometric moisture. M. Dulong, however, observes, and with truth, that apparently unimportant variations in the manner of conducting the experiments would greatly influence the results, and that Mr. Haycraft has not furnished sufficient details to enable his readers to judge of the amount or direction of the errors by which they were likely to be affected.

The objections to the researches of Marcet and De la Rive are of a much graver nature. These philosophers included the different gases successively in the same globe of glass, and having determined experimentally the times that each thus enclosed took, when exposed to a constant heat, to acquire the same rise of temperature, these times were concluded to be proportional to their specific heats. To obtain, however, the times of heating of equal volumes of the different gases, it is obvious, that we must subtract from those given by experiment the times in which the glass balloon—supposed perfectly exhausted—would undergo the same change of temperature. But owing to the insignificant amount of the mass of the gas compared to that of its envelope, this difference will necessarily always be so small, as to be, in all probability, frequently exceeded by the inevitable errors of observation. Besides, as Dulong observes, and as was shown by him and Petit in their celebrated prize essay on the Laws of Cooling in different Elastic Media, the times of heating of the different gases in the experiments of Marcet and De la Rive, depended not exclusively upon their respective specific heats, but also greatly upon their specific gravities. For these reasons M. Dulong does not hesitate to affirm, "that the results of De la Roche and Berard are still those which should inspire most confidence, and that though they cannot be considered as having attained perfect precision, they are amply sufficient for putting beyond all doubt that the various simple and compound gases have not, under the same volume, an equal capacity for heat."

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* They are, of course, all supposed to be submitted to the same pressure.

Having disposed of these preliminary animadversions upon the labours of some of his predecessors, M. Dulong proceeds to the explanation of the particulars of a very ingenious method practised by himself, for determining—not the specific heats—either at a constant volume, or under a constant pressure, but the ratio which subsists between these quantities in the case of the different gases. If a be the caloric necessary to be communicated to a given weight of any gas in order to produce in it, maintained of a constant volume, a given increase of temperature, and $a+b$ the caloric necessary to produce the same change of temperature, when the gas is permitted to expand so as to retain its primitive elasticity, $\frac{a+b}{a}=1+\frac{b}{a}$ expresses the ratio in question, and is the quantity at which Dulong, by his method of research, was enabled in the following manner to arrive.

The Newtonian formula for the velocity of sound, viz.

$$v=\sqrt{\frac{gh}{d}\times(1.+00375t)},$$

is long known to give results appreciably less than the truth, but Laplace was the first who pointed out the cause of the discrepancy, and showed that Newton's expression should be multiplied by the square root of the relation between the specific heat of air under a constant volume and a constant pressure, a correction which is at present found to give results in almost perfect accordance with observation. If, therefore, the velocity of sound in atmospherical air be determined experimentally, and that this be divided by the Newtonian expression, the quotient will be $\sqrt{\frac{a+b}{a}}$, or the square root of the relation between its specific heat under a constant volume and a constant pressure; and the same method may obviously be extended to all the gases,* provided we can determine the exact velocity of sound in each.

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* The Newtonian expression,

$$v=\sqrt{\frac{gh}{d}(1+,00375\,t)},$$

is applicable to any gas by substituting for d the s. g. of the gas in relation to mercury.

This indispensable datum Dulong deduced from certain experiments with a flute-like pipe or tube, blown through by the different gases, from which, by the application of the theory of wind instruments, he was enabled to calculate the length of a single vibration, and the number performed in a given time, for several of the elastic fluids.

The velocities thus obtained were then divided by their values as given by Newton's formula, and the quotients squared necessarily represented, as has been already shown, $1+\frac{b}{a}$, or the relation for each gas between its specific heat under a constant volume and a constant pressure. The following are the results to which he was thus conducted :—

	$1+\frac{b}{a}$	Specific Heat under constant volume.	Specific Heat under constant pressure.	Specific Heat const. press. De la Roche and Berard.
Atmospheric Air........	1.421	1.000	1.000	1.000
Oxygen	1.415	1.000	1.000	0.976
Hydrogen	1.407	1.000	1.000	0.903
Carbonic Acid..........	1.338	1.245	1.172	1.258
Carbonic Oxide	1.428	1.000	1.000	1.034
Nitrous Oxide..........	1.343	1.227	1.159	1.350
Olefiant Gas	1.240	1.754	1.530	1.553
	(1)	(2)	(3)	(4)

A glance at the first column of this table would appear sufficient to justify the conclusion, that the mixed number which represents the relation in question, is the same for all the simple gases, but that this law does not extend to those of a compound nature, with the exception of carbonic oxide.

If b have the same value for all gases, simple or compound, or, as is indeed extremely probable, if all, in undergoing the same degree of compression, give out the same amount of heat, a, must vary reciprocally as $\frac{b}{a}$, that is the specific heats, under a constant volume, will vary reciprocally, as the fractions in column (1.) Upon this hypothesis, values of a, the specific heat under a constant volume, have been calculated for each gas, that of air being represented by unity, and are set down in column (2). In column (3) we have values of $a+b$, the specific heat, under a constant pressure, which are obtained by multiplying the corresponding numbers, in columns (1) and (2), and dividing all the products by

1.421, in order that the representative of air should be unity. Column (4) exhibits the specific heats under a constant pressure, as deduced by De la Roche and Berard.

The numbers in column (2) correspond so well with those in column (4), which were experimentally obtained, that Dulong conceives himself entitled to enunciate, as proved, the two following propositions, the first of which he has assumed in his calculations.

1st. That equal volumes of all gases, at the same temperature and pressure, evolve by a given condensation the same amount of caloric.

2nd. That the rise of temperature produced in each gas, by the heat so extricated, is reciprocally proportional to its specific heat, under a constant volume.

At the close of his paper, which was read before the Academy of Sciences, in May, 1828, M. Dulong states, that he was then engaged in researches, in reference to the influence of variations of pressure and temperature, on the specific heats of gases, the results of which he hoped to be shortly able to give to the public in a second memoir, in which it was his intention also to investigate the laws which connect the specific heats of the compound gases with their actual composition. Eight years, however, have now elapsed since this promise was made, and I am sorry to add, (indeed it will be considered matter of general regret,) that it has not as yet been redeemed.

The method of Dulong, just explained, is partly experimental, and partly hypothetical. To the principle on which his experiments were conducted, no possible objection can be urged, and I apprehend that the numbers at which he arrived represent, with considerable precision, the ratios of the specific heats of the gases on which he operated, in the two different predicaments to which allusion has so frequently been made. Doubts, however, may be entertained as to the truth of his hypothetical premiss, that all gases, in virtue of a given compression, evolve the same amount of caloric; and if this be incorrect, his conclusions in reference to the specific heats of the gases under a constant volume, or a constant pressure, must also be erroneous.

These observations are thrown out, with the view of pointing attention to what may be considered as proved, and what assumed, in the paper of Dulong; and of showing, that, even after his elaborate researches, the subject under consideration must still be considered as constituting an open question. At all events, assuming such to be the case, I shall, without further preface, proceed to explain the particulars of a new method which I have adopted for comparing the capacities for caloric, of the different æriform fluids.

In a paper which I had the honour of reading in November last, before the Royal Irish Academy, I showed that the formula

$$f'=f''-\frac{48ad}{e}\times\frac{p}{30}$$

expresses the relation between the indications of the wet bulb hygrometer and dew-point; e being the caloric of elasticity of vapour, at the temperature t' of the hygrometer; a, the specific heat of air; $d=t-t'$, the difference between the temperature of air and hygrometer; and f' and f'', the elastic forces of the vapour of water, at the temperatures of the hygrometer and dew-point. If, therefore, the dew-point and temperature of hygrometer be taken in each of the gases, their specific heats become known, for in each case, as may be easily deduced from the expression given above,

$$a^{*}=(f'-f'')\frac{e}{48d}\times\frac{30}{p}.$$

Such a method, though theoretically exact, is beset with such difficulties, that it may, I think, be considered as practically impossible. The artificial gases, as usually collected, are saturated with moisture—a state in which they are quite unsuited for the necessary experiments; and even though this difficulty were overcome, it would, I conceive, be nearly impossible to determine their dew-point by direct observation.

By recurring, however, to the former equation,

$$f''=f'-\frac{48ad}{e}\times\frac{p}{30},$$

and modifying it, so as to suit a particular case, a much simpler method of investigation is suggested. If the air be supposed perfectly dry, $f''=o$, and

$$a=\frac{ef'}{48d}\times\frac{30}{p},$$

an expression involving no unknown quantity but d, and which will therefore

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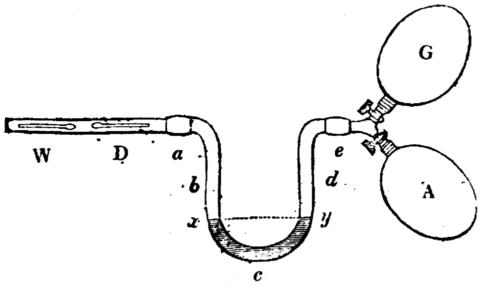
a, is here assumed to represent the specific heat under a given volume of the gas, which is the subject of experiment.

enable us to calculate the specific heat of a gas, when we have observed the stationary temperature to which, when in a state of perfect desiccation, it brings the wet bulb thermometer. The experiments subservient to this method are easily made; and the gases being dry, their specific heats are not affected by the presence of vapours, the influence of which, by the way, we are probably not in a predicament to appreciate with the necessary degree of precision.

The method, therefore, which I have, I believe, been the first to adopt, consists in determining, by experiment, in the case of the several gases deprived of all hygrometric measure, t and t', and consequently $t-t'=d$, and deducing in each instance from these data the value of a, the specific heat.

In order to the determination of d, the following apparatus, and method of experimenting was, after a trial of several others, finally adopted :—



a b c d e is a glass tube, 3-10th of an inch in diameter, and whose vertical arms are each about twenty inches long. Into this inverted syphon oil of vitriol was poured, so as to rise to the height of about two inches in each leg; and to the horizontal portion of each of these there were connected, through the medium of a three-armed copper tube, two bladders, A and G, furnished with stop-cocks, one of which was filled with air, and the other with the gas which was to be the subject of experiment; while to the other extremity of the syphon there was attached, also by a caoutchouc collar, a glass tube, in which were placed the dry and moist thermometers, as represented at D and W. Every thing being thus arranged, an assistant pressed by means of a deal board on the air bladder, by which its contents were forced through the oil of vitriol, where they were deprived of vapour, and over the dry and wet thermometers, producing in the latter a considerable fall of temperature; and the moment that the air bladder was exhausted, its stop-cock was rapidly closed, that of the other opened, and the experiment continued by means of pressure similarly applied to the gas. While matters were thus proceeding, I kept my eye, armed with a common lens, steadily fixed on the wet thermometer, and the moment that it acquired a stationary temperature, (which, generally speaking, in consequence of the previous current of dry air, occurred long before the entire of the gas was discharged,) its indication, and that of the dry thermometer, were registered, and the experiment suspended. The residual gas was now passed into a glass jar on the mercurial trough, with a view to subsequent analysis, and both bladders being refilled with atmospherical air, a second experiment was performed precisely as just described.

The values of t and t', obtained in the first experiment, enabled us to calculate, by aid of the equation

$$a = \frac{ef'}{48d} \times \frac{30}{p},$$

the specific heat of the elastic fluid which was made to traverse the apparatus. But this result belonged not to the pure gas, but to a mixture of it with a certain quantity of atmospheric air, which enters the bladder upon the principle of endosmose, and to infer from it the specific heat of the pure gas, which we shall call a', it was necessary to know the amount of air present, and its specific heat. Now the former of these was given by the analysis of the residual gas, as already mentioned, and the latter by the results of the second experiment above recorded, in which both bladders were occupied by air alone.

If a' be the specific heat* of the gas, n the percentage of air, c its specific heat, and a the specific heat of the mixture of air and gas, we will, on the principle that the specific heat of the mixture, multiplied by its volume, is equal to the sum of the products of the respective volumes of air and gas, multiplied by their respective specific heats, have

$$a' \times (100 - n) + nc = a \times 100,$$

an equation from which we deduce

$$a' = a + \frac{(a-c)n}{100-n}.$$

This is the specific heat of the pure gas in reference to that of air, as determined by the second of the above experiments; and as both air and gas are dry, and must have been, with at least a high degree of probability, proportionally affected by variations of pressure, the precise influence of these, about which, indeed, philosophers are not agreed, do not require to be taken into consideration, nor is there any thing farther necessary for rendering the result thus obtained strictly comparable with those of other experiments, than to reduce it by the Rule of Three to what it would be if the specific heat of air were .267, the number by which it is usually represented in books, at the mean altitude of the barometer. I shall now, before proceeding to the tabular view of my experiments, and their results, exemplify the method of calculation which has been just described.

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* The specific heats spoken of throughout this paper are those under a given volume.

On the 4th of August, 1835, the following observations were made, first on hydrogen, and subsequently upon air.

	t	t'	d	p
Hydrogen . . .	68	48	20	30.114.
Air	68	43	25	30.114.

By applying to these results the equation $a = \frac{ef'}{48d} \times \frac{30}{p}$, we get

Specific heat of air . . . . $= .2767 = c$.
Approximate specific heat of gas . $= .409 = a$.

But the gas, upon analysis, was found to contain 5 per cent. of air. Hence the specific heat of the hydrogen supposed pure, as deduced from the equation

$$a' = a + \frac{(a-c)n}{(100-n)},$$

becomes, .4151. And as, .2767 : .4151 : : 2670 : .4005, the specific heat of hydrogen compared to that of air under a pressure of 30, when water is represented by unity, or what amounts to the same, when air is .267.

The following tables include the particulars of the first series of experiments I performed on this interesting subject. In order that they may be perfectly understood, the reader should recollect that t is the temperature of the dry, and t' of the wet thermometer; that $d = t - t'$; that p is the existing pressure, as measured by the barometer; a the specific heat of gas, as deduced from the formula

$$a = \frac{ef'}{48d} \times \frac{30}{p};$$

a' the same corrected by the formula

$$a'=a+\frac{(a-c)n}{100-n},$$

for the percentage of atmospheric air present; and a'' the specific heat reduced to what it would have been if the corresponding experiment on air had given as result, .267. Table (1) relates to atmospheric air alone, and table (2) to the other gases. In table (3) we have the results stated in table (2) referred to atmospheric air represented both by .267 and by unity.

(1)

	t	*t'*	*d*	*p*	*a*
June 21.	58.8	38.4	20.4	30.014	.2912
27.	52.7	34.9	17.8	30.225	.2935
July 31.	64.5	41.2	23.3	30.330	.2773
August 1.	67.3	42	25.3	30.140	.2624
4.	68	43	25	30.114	.2767
5.	67	42.4	24.6	30.000	.2768
7.	66	44.7	24.3	30.218	.2657
					.2776

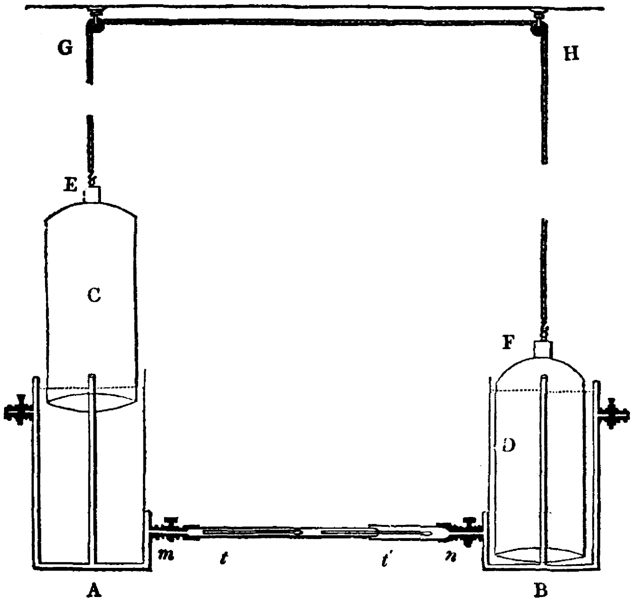
(2)

		t	*t'*	*d*	*p*	*a*	Air per Cent.	*a'*	*a''*	Means.
Azote	June 27.	53.8	35.5	18.3	30.225	.2915		.2915	.2912	.2660
	July 31.	65	41.3	23.7	30.330	.2735		.2735	.2669	
Carbonic Acid .	June 21.	60	40	20	30.014	.3135	11.4	.3137	.2876	.2910
	27.	53.8	36.5	17.3	30.225	.3178	12	.3211	.2921	
	July 31.	65.2	42.7	22.5	30.330	.3021	8.2	.3043	.2933	
Carbonic Oxide.	August 1.	67.3	43.5	23.8	30.140	.2952		.2952	.3003	.2863
	5.	67.5	43	24.5	30.000	.2874		.2874	.2772	
	7.	66.2	42.4	23.8	30.218	.2774		.2774	.2825	
Hydrogen	June 21.	59	42.8	16.2	30.014	.4262	4	.4317	.3961	.4022
	27.	52.3	38.9	13.4	30.225	.4475	7	.4590	.4175	
	July 31.	65	46	19	30.330	.4000	7.5	.4099	.3946	
	August 4.	68	48	20	30.114	.4092	5	.4151	.4005	
Nitrous Oxide .	August 4.	67.5	44.5	23	30.114	.3173	27.5	.3327	.3210	.3147
	7.	65	42.5	22.5	30.218	.3013	14	.3071	.3085	

(3)

	Specific Heats of equal Volumes.	
Atmospheric Air	.2670	1.000
Azote....................	.2660	.996
Oxygen, (by calculation)	.2710	1.015
Hydrogen	.4022	1.506
Carbonic Acid	.2910	1.090
Carbonic Oxide............	.2863	1.072
Nitrous Oxide	.3147	4.179

Upon these results I never placed much reliance. The apparatus employed was very imperfect, particularly in not permitting more than a single experiment on the same quantity of gas; and I also saw reason to doubt that I had in every instance by means of it accomplished perfect desiccation. Under these circumstances I always contemplated returning to the subject, and towards the latter end of last July, I did actually commence a fresh series of experiments, which were conducted on the following plan.



A pair of copper gasometers, A, B, with glass bells, C, D, such as are usually employed by chemical lecturers, were charged with a proper quantity of oil of vitriol, instead of water, and placed upon a table at the distance of three feet from each other, the brass caps, E, F, attached to the bells, being suspended to the extremities of a stout cord passing over a pair of runners, G, H, fixed in the ceiling of the laboratory, the length of the cord being such, that while one of the bells was almost entirely immersed in the oil of vitriol, the other dipped about an inch beneath its surface. Between the lower stop-cocks, m, n, attached to the gasometers, a couple of glass tubes were interposed, connected to the stop-cocks by caoutchouc collars, and fitting at their other extremities to each other by a tight ground joint. In the larger of these tubes the dry thermometer t was permanently placed, and into *it* also the wet one t' was introduced previous to the commencement of an experiment. Matters being, we shall suppose, thus prepared, and the unimmersed bell, *c*, occupied, *first* with atmospherical air, deprived by the oil of vitriol of its moisture, pressure was made upon it by an assistant, so as to force its contents in a rapid current into the second bell, D, through the tube containing the wet and dry thermometers. During this operation the observer kept his eye, armed with a lens, steadily fixed on the thermometers, and registered the indications of both as soon as the wet one became and continued stationary for a few seconds. The height of the barometer being now taken, the necessary *data* were obtained for calculating, from the formula

$$f'' = f' - \frac{48ad}{e} \times \frac{p}{30},$$

the elastic force of the vapour still existing in the air of the gasometer. The atmospheric air being now replaced by one of the gases which were to be the subject of experiment, and left sufficiently long in contact with the oil of vitriol, the very manipulations and observations just detailed were repeated. This same experiment, with sufficient intervals to allow in each instance of maximum desiccation, was again and again performed; and it having been ascertained, after a considerable number of repetitions, that the results were uniform and consistent, and that they might therefore be relied upon, the mean of all the observations was taken, and from this the specific heat of the gas deduced by means of the formula

$$a = (f' - f'') \times \frac{e}{48d} \times \frac{30}{p},.$$

that value being assigned to f'' which resulted from the preliminary experiments on atmospherical air. The analysis of the gas was next very carefully performed, and it having been ascertained that n volumes *e. g.* of atmospheric air per cent. were present, the proper correction was applied by the formula

$$a' = a + \frac{(a-c)n}{100-n},$$

in which $c = .267$ is the specific heat of air, a' the true specific heat of the gas, and a the specific heat of mixture of gas and air as previously determined. Such was the course pursued in the case of each of the gases submitted to experiment.

The particulars of the entire series are comprehended in Tables (1) and (2), the first of which relates to air alone, the second to the different other gases. Table (3) contains the final results, alongside of which are placed the numbers of De la Roche and Berard, and those of Dulong, for the purpose of comparison.

(1)

1836.	t	t'	d	p	f''
August 8......	63.5	40.3	23.2	30.226	
8......	63.2	40.1	23.1	30.226	
8......	63.2	40	23.2	30.226	
Mean	63.3	40.1	23.2	30.226	.0024
August 9......	62.8	40.5	22.3	30.250	
9......	63	40.8	22.2	30.250	
9......	62.9	40.6	22.3	30.250	
9......	63.5	41.1	22.4	30.250	
9......	63.2	40.8	22.4	30.250	
Mean	63.1	40.7	22.4	30.250	.0134
Aug. 10......	63	40.7	22.3	30.208	
10......	64	41.5	22.5	30.208	
10......	63.4	41.2	22.2	30.208	
10......	63.6	10.9	22.7	30.208	
Mean	63.5	41.1	22.4	30.208	.0114
Aug. 11......	62.2	40.9	21.3	30.310	
11......	63	40.9	22.1	30.310	
11......	63	41.5	21.5	30.310	
11......	63.8	41.5	22.3	30.310	
11......	63.2	41.7	21.5	30.310	
11......	63.2	41.3	21.9	30.306	
11......	64	41.4	22.6	30.306	
Mean	63.2	41.3	21.9	30.307	.0241
Aug. 12......	66.5	41.8	24.7	30.270	.0063
15......	65.8	41.9	23.9	30.070	——
15......	66.5	41.4	25.1	30.070	
15......	66.6	41.9	24.7	30.070	
Mean	66.3	41.7	24.6	30.070	.0027

(2)

1836.		*t*	*t′*	*d*	*p*	*a*	Air per Cent.	*a′*
Carbonic Acid ..	August 8..	62.5	41.5	21	30.226		10.2	
	8..	62.6	41.5	21.1	30.226			
	8..	63	41.9	21.1	30.226			
	8..	63	42.3	20.7	30.226			
	8..	63.6	42.4	21.2	30.226			
	8..	63.7	42.4	21.3	30.226			
	8..	63.2	42.1	21.1	30.226		11.4	
	Mean......	63.1	42	21.1	30.226	.3136	10.8	.3992
Hydrogen........	August 8..	63.6	45.1	18.5	30.226	.3970	3.2	.4012
Hydrogen	August 9..	62.1	44.1	18	30.260		3.2	
	9..	62.6	44.1	18.5	30.260		3.6	
	9..	63	44.7	18.3	30.260		4	
	9..	62.8	44.7	18.1	30.260		4.4	
	9..	63	44.6	18.4	30.260		4.8	
	9..	63.8	45.1	18.7	30.250		5.2	
	9..	63	44.6	18.4	30.250		5.7	
	Mean......	62.9	44.5	18.4	30.257	.3734	4.3	.3781
Nitrous Oxide ..	August 10..	62.1	42.1	20	30.200		14	
	10..	63	42.4	20.6	30.205			
	10..	63.6	42.6	21	30.210			
	10..	63	42	21	30.210			
	10..	63.5	42.5	21	30.210			
	10..	63.4	42.6	20.8	30.210		16	
	Mean......	63.1	42.3	20.8	30.207	.3109	16	.3186
Equal volumes of Carbonic Acid and Carb. Oxide	August 11..	64.9	42.8	21.1	30.306			
	11..	05.4	43.3	22.1	30.306			
	11..	65.3	43.3	22	30.306			
	Mean......	65.2	43.1	22.1	30.306	.2865		.2865
Equal volumes of Carbonic Acid and Carb. Oxide	August 12..	65.3	42.7	22.6	30.27			
	12..	65.8	43.4	22.4	30.27			
	12..	65.8	42.3	23.5	30.27			
	12..	65.3	42.6	22.7	30.27			
	Mean......	65.5	42.7	22.8	30.27	.2988		.2988
Nitrogen......	August 15..	64.8	41.9	22.9	30.07			
		66.8	42.3	24.5	30.07			
		66	42	24	30.07			
	Mean......	65.9	42.1	23.8	30.07	.2799		.2799

(3)

Specific Heats of equal Volumes.

	J. A.		De la Roche and Berard.	Dulong.
Atmospheric Air..............	.2670	1.000	1.000	1.000
Nitrogen.....................	.2799	1.048	1.006	1.000
Oxygen*.....................	.2154	.808	.976	1.000
Hydrogen	.3896	1.459	.900	1.300
Carbonic Acid................	.3192	1.195	1.258	1.172
Carbonic Oxide†..............	.2660	.996	1.034	1.000
Nitrous Oxide................	.3186	1.193	1.350	1.159

I shall conclude with the following propositions, which, if not established by, are, at least, in accordance with the results of my researches.

1st. The simple law so much insisted upon in modern times by Haycraft, Marcet, and De la Rive, and others, that equal volumes of the different gases have the same specific heat, is not the law of nature.

2nd. The more limited proposition enunciated by Dulong, that the *simple* gases have under a given volume the same specific heat, is probably not true in a single instance,‡ and is altogether at variance with my result for hydrogen.

3rd. The numbers at which I have arrived correspond tolerably well with those of De la Roche and Berard, except in the case of hydrogen.

4th. There does not seem to be any simple relation between the specific heats of the gases, and their specific gravities or atomic weights; and philosophers, in searching for such, are probably pursuing a chimera.

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* My number for this gas is deduced from that for nitrogen by the formula $x + 4 \times .2799 = 5$, in which x is the specific heat of oxygen, and .2799 that of nitrogen.

† My number for this gas is inferred by calculation from that given by experiment for the mixture of it with an equal volume of carbonic acid. The formula is $x = m + m - .3192$, x being the specific heat of carbonic oxide, .3192 of carbonic acid, and m of the mixture.

‡ I would not wish to be understood as speaking with much confidence of the numbers attached to nitrogen and oxygen. But three experiments were made, in consequence of one of the gasometers having begun to leak; and, moreover, as nitrogen was the gas operated with, in passing by calculation to the specific heat of oxygen, the errors of observation would be multiplied by four. Oxygen, in fact, not nitrogen, should have been the subject of experiment.